Application Report
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Optical Implementation Using IEEE-1394.b

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ABSTRACT

IEEE Std 1394b-2002 specification allows the use of optical media for longer distances at higher speeds. The use of optical media provides galvanic isolation, lower electromagnetic interference (EMI), and lower interference from the environment.

Interfacing 1394.b physical-layer devices (PHYs) may require additional components, depending on the type of fiber-optic transceiver (FOT) selected. This application report addresses the issues associated with using optical transceivers for 1394.b networks with the TI TSB81BA3 PHY device (S800) and TI TSB41BA3 PHY device (S400 and below).

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1 Introduction

Many existing products contain IEEE Std 1394a-2000 (trademarked by Apple as Firewire™ and by Sony as i.Link™) ports. Before the release of IEEE Std 1394b-2002, the distance between nodes was limited to approximately 4.5 meters. To overcome this limitation for longer distances and faster speeds, 1394.b defines a different coding scheme. The new coding scheme allows 1394.a devices to be interconnected using longer cables and a variety of media types by using a bilingual 1394.b device. Bilingual devices can connect using data/strobe signaling, as defined in 1394.a, or beta-mode signaling, as defined in 1394.a. Figure 1 shows a method of connecting two 1394.a-compliant devices using 1394.b.

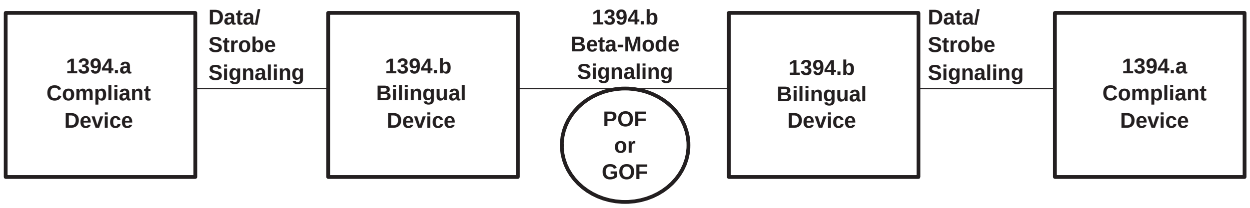

Figure 1. IEEE-1394 Mixed (1394.a and 1394.b) Network

While standard copper cables still are an option, longer distances can be achieved with plastic optical fiber (POF) or glass optical fiber (GOF). In addition to the longer distances, the electromagnetic compatibility (EMC) performance is better with the inherent characteristics of optical networks. Also, the 1394.b standard defines copper connections over longer distances (see Table 1).

Table 1. Summary of Supported Media for 1394.b

MEDIA	REACH	SUPPORTED SPEEDS					
		S100	S200	S400	S800	S1600	S3200
UTP-5	100 m	✓			✓ (being studied)		
POF/HCPF	100 m	✓	✓ (50 m for POF)	✓ (future POF?)			
50-µm GOF	100 m	✓	✓	✓	✓	✓	✓
STP (beta)	4.5 m	✓	✓	✓	✓	✓	✓
STP (DS)	4.5 m	✓	✓	✓			

2 Establishing a 1394.b Connection

A bus built using 1394.b, as with 1394.a, is hot-pluggable. To detect a connection, a tone signal is generated and transmitted on twisted-pair B (TPB+/−). When a node also receives a tone signal, it recognizes that a connection has been made. Once a valid tone is detected, the nodes go through a speed-negotiation sequence. Additional tones are sent at specified intervals to indicate speed capabilities. Once the nodes agree on a speed at which both nodes can communicate, an acknowledge tone is sent. Following the speed-negotiation process, the nodes can start sending symbols and align their clocks (also called training). After the training sequence is complete, idle symbols are sent continually until data transfers are sent. Figure 2 shows an example of the connection sequence.

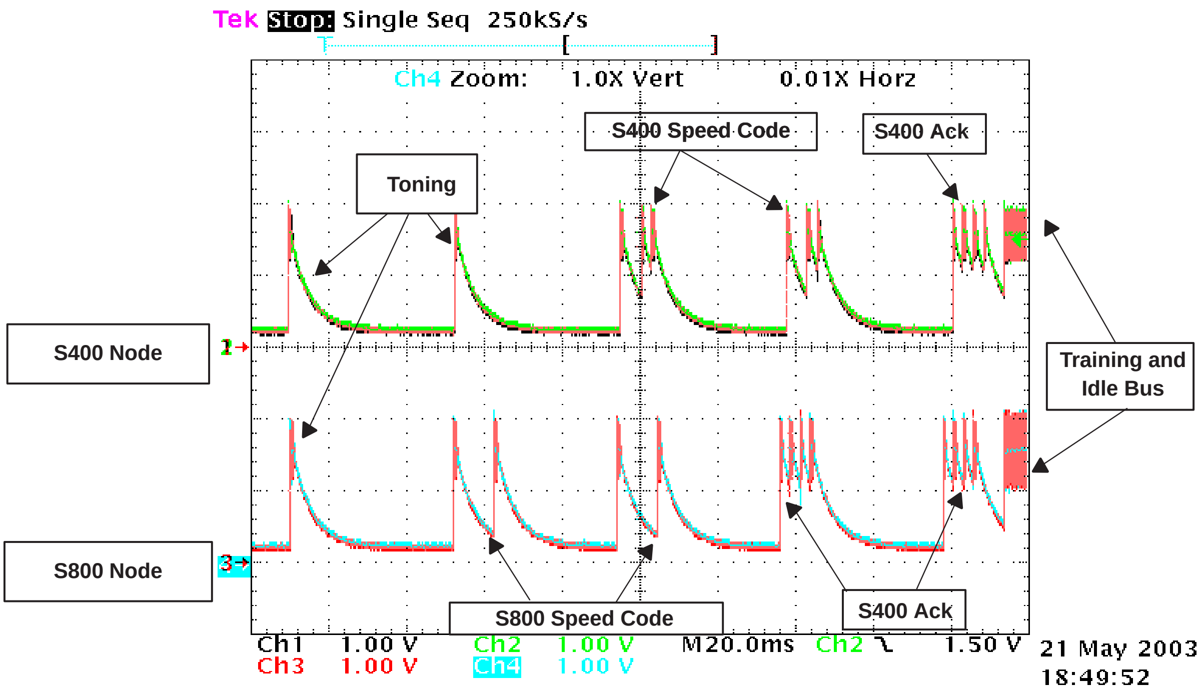

Figure 2. 1394.b Toning Connection Sequence

Figure 2 shows two nodes (one node set for S400 and the other set for S800). The waveform shown is at the TPA+/− pins of the receivers that see the transmitted signal from TPB+/− of the connected node. In 1394.b beta-mode signaling, the TPB+/− signals always are designated as transmit and the TPA+/− always are designated as receive. This is different from 1394.a data/strobe signaling. The beginning of the waveform shows both nodes toning, speed signaling, acknowledging, training, and, finally, connecting. It is this toning and connection sequence that must be handled properly by the optical transceivers and reproduced at the receiving node (see IEEE Std 1394b-2002, Section 14, *Connection Management*).

Figure 3 shows the toning interval and duration when there is no trained connection. The tone is a 50-MHz signal, 667 µs wide, that occurs every 42.7 ms. At the receiver of the PHY, the tone must be a minimum of 400 µs wide, to be considered a valid tone. During the tone, the transmitter TPB signals are compliant to the level specified in the 1394.b standard. Between tones, the transmitter is placed in the high-impedance state.

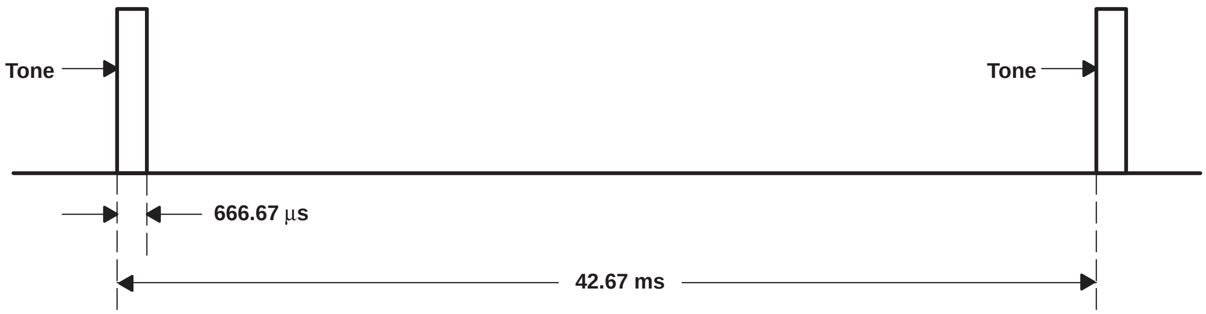

Figure 3. Toning Interval and Duration

3 PHY to Fiber-Optic-Transceiver (FOT) Connections

The signal levels between a 1394.b device and a FOT may not be compatible, depending on the interface level of the FOT. Figure 4 shows the basic components of a connection between a 1394.b PHY and a FOT.

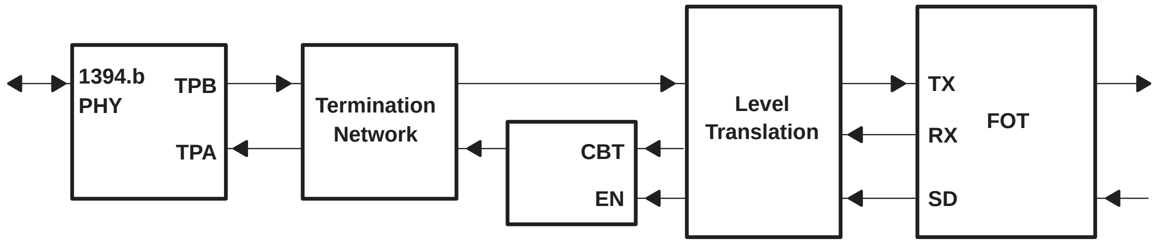

Figure 4. Basic Fiber-Optic Components

3.1 Termination Network

The termination network is the network described in IEEE Std 1394b-2002. Figures 5 and 6 show the termination network. The termination network should be included between the PHY and FOT, but close to the PHY. In addition, the twisted pairs should be matched in length and 110-Ω differential impedance. Figure 5 shows the connections to a positive-emitter coupled logic (PECL)-level FOT (Agilent GOF transceiver, P/N HFBR-53D5, is shown). Figure 6 shows connections to a low-voltage positive-emitter coupled logic (LVPECL)-level FOT (Toshiba POF transceiver, P/N TODX2402, is shown).

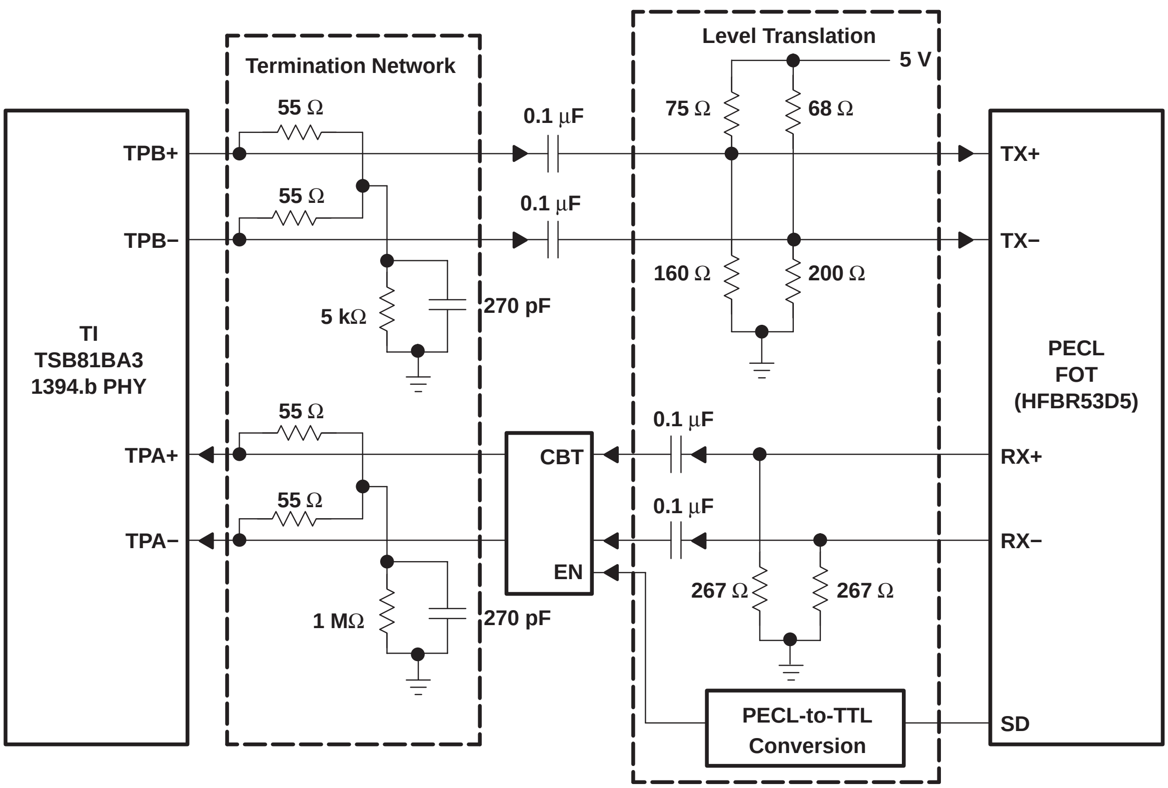

Figure 5. Connections to PECL FOT

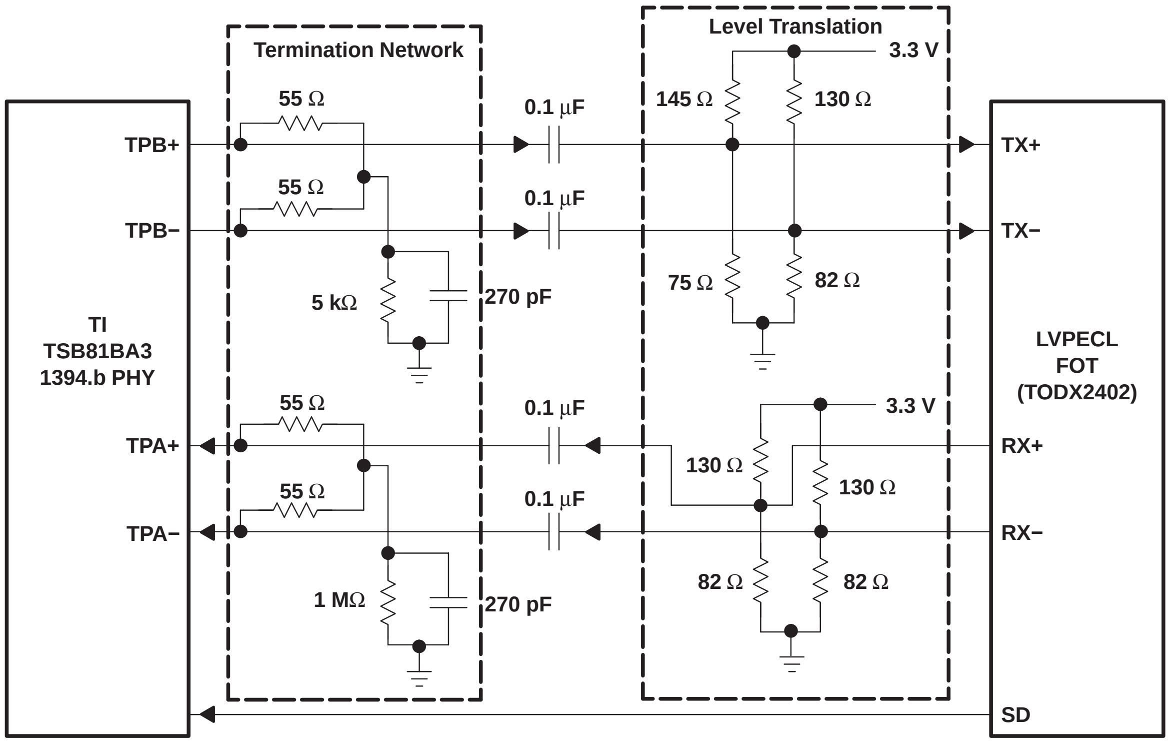

Figure 6. Connections to LVPECL FOT

3.2 Level Translation for FOT Transmitter

Some level translation may be required on the transmit inputs to the FOT transceiver. The transmit signals can be ac coupled to allow for translating levels using only discrete components. A network is used to provide bias signals to the FOT. Figures 5 and 6 are examples of level translation for PECL and LVPECL transceivers, respectively. The network at the FOT is similar to the network specified in the data sheets for the respective FOTs noted in the figures. The network shown is similar, but with slight modifications to prevent noise from being transmitted by the transceiver between tones. One method used to prevent the transmission of noise is to provide a slight biasing off of the differential signals. The biasing off of the transmitter is successful only if the FOT transmitter is not ac coupled.

If the transmitter is ac coupled, a different approach may be needed. Some optical transceivers have a transmit enable that can be used for the same purpose, if the transmit enable delay is less than 100 µs. Figure 7 shows an example of a connection diagram using the transmit enable for an FOT with ac-coupled transmit inputs. Notice that the comparator in Figure 7 compares the differential signal level from the PHY to approximately 0.8 V.

Again, the twisted pairs should be matched in length.

NOTE: The tone at the receiving PHY must meet the minimum duration requirement of 400 µs. Using the transmit enable, the delay should be 100 µs, or less. Regardless, the tone of 667 µs should not be shorter than 400 µs after accounting for all the delays through both ends of the system.

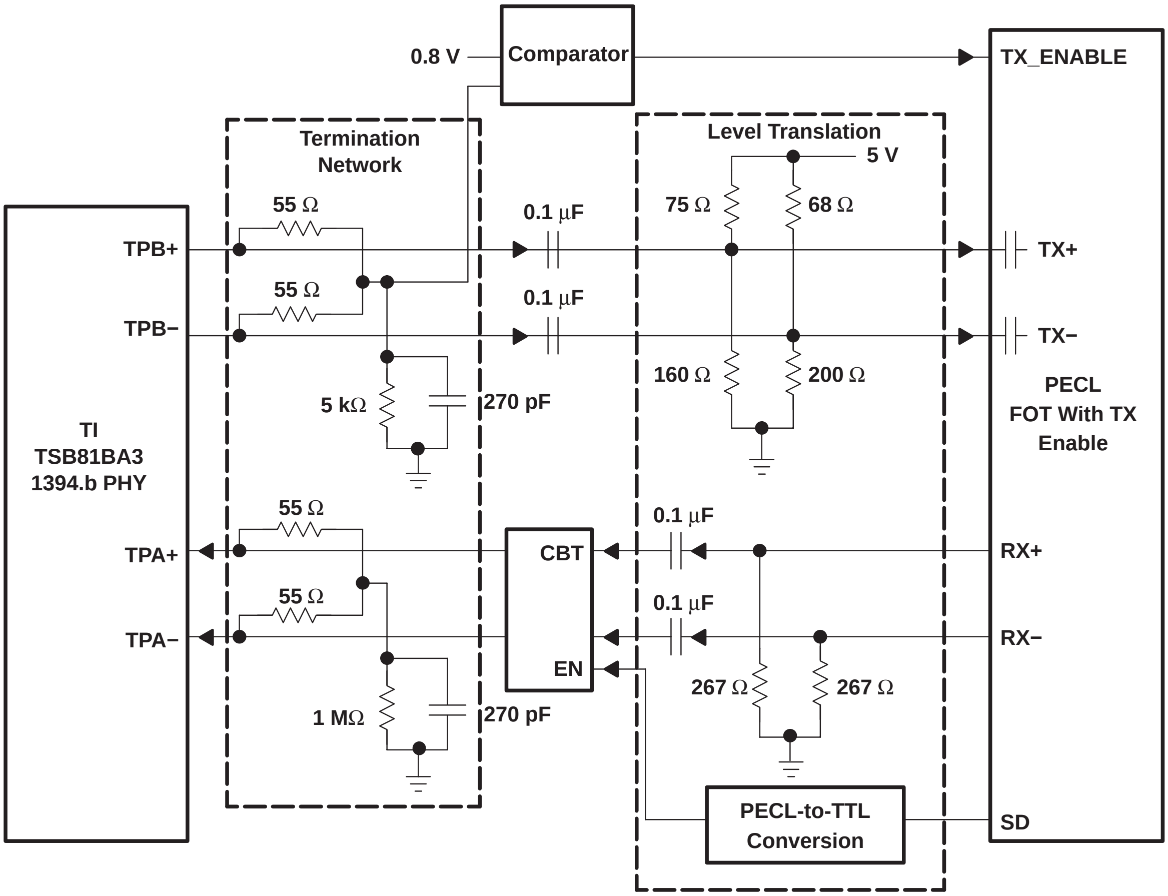

Figure 7. Connections for Internally AC-Coupled PECL FOT With Transmit Enable

3.3 Receiver Network

At the receiver, the proper termination network must be present for the type of FOT used. Figures 5 and 6 show examples of PECL and LVPECL FOT networks, respectively. The data sheet for most FOTs has a reference network. Typically, FOT receivers amplify the incoming signal level, and presume there always is a valid signal at its inputs. When no signal is present between tones, the receiver may output noise. To ignore this spurious noise, a set of crossbar technology switches can be used to generate a high-impedance state between tones. These switches must be enabled when there is a valid signal detected at the FOT inputs and must not be opened when no valid signal is detected. Therefore, a transceiver with a signal-detect function is needed to control the crossbar switches.

If the signal-detect signal is an LVCMOS signal, it can be used to control the crossbar switch directly. Some FOTs are LVPECL and must be shifted. The signal level at the crossbar switch enable must be compatible with the particular device selected. Figures 5 and 7 show diagrams of a receiver with signal detection that requires level translation. Figure 6 shows a receiver with signal detection that does not require level translation. As mentioned in the data sheets, the TI PHYs have internal ac coupling on the receiver inputs TPA+/−. On the board, the TPA differential pairs should be matched in length, similar to the TPB line.

For connections to the TSB81BA3 PHY, the crossbar switch must be implemented externally. The TSB41BA3 PHY includes the switches internal to the device. The TPBIAS_SDx signal can be used to control the internal switches in a beta-only mode configuration for a signal port.

NOTE: The tone at the receiving PHY must meet the minimum duration requirement of 400 µs. It is recommended that the signal-detect delay be 100 µs, or less. Regardless, the tone of 667 µs should not be shorter than 400 µs after accounting for all the delays through both ends of the system.

4 Conclusion

1394.b PHY connections to FOTs must be able to handle the connection sequence, as well as the full operating condition. Depending on the transceiver, signal levels between devices may require translation. The transmitter should be biased off between tones to avoid sending noise between tones. In general, dc-coupled transmitters are required, unless the transmit enable can respond quickly enough to send a valid tone. On the receive side, a signal detect is needed if the receiver is sensitive. The signal detect then is used to control some CBTs to create the high-impedance signal between tones. By taking the previously outlined considerations into account, optical networks can be built using IEEE 1394.b.

5 References

The following documents might be helpful. For TI documents, go to www.ti.com and search for the document literature number as the keyword.

TSB81BA3, TSB81BA3I IEEE 1394.b Three-Port Cable Transceiver/Arbiter data sheet (literature number SLLS559).

TSB41BA3 IEEE 1394.b Three-Port Cable Transceiver/Arbiter data sheet (literature number SLLS155).

AC Coupling Between Differential LVPECL, LVDS, HSTL, and CML, application report (literature number SCAA059*).*

SN74CB3Q3125 Quadruple FET 2.5-V/3.3-V Low-Voltage High-Bandwidth Bus Switch (literature number SCDS143A).

SN74CBT3126 Quadruple FET Bus Switch, application report (literature number SCDS020J).

TL714 High-Speed Differential Comparator With Push-Pull Outputs, data sheet (literature number SLCS0105).

TPS76901 Ultra-Low-Power 100-mA LDO Line Regulators, data sheet (literature number SLVS203E).

HFBR-53D5 1× 9 Fiber-Optic Transceivers, Agilent data sheet.

TODX2402 Fiber-Optic Transceiver Module, Toshiba data sheet.

HFAN-01.1: Choosing AC-Coupling Capacitors, Maxim application note.

6 Abbreviations

PHY	Physical-layer device
FOT	Fiber-optic transceiver
POF	Plastic optical fiber
GOF	Glass optical fiber
PECL	Positive-emitter coupled logic
LVPECL	Low-voltage positive-emitter coupled logic
CBT	Crossbar transceiver

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